ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS119

STATUS OF THE ESS MEDIUM BETA CAVITIES AT INFN - LASA

P. Michelato†, M. Bertucci, A. Bignami[1], A. Bosotti, M. Chiodini[2], A. D'Ambros, L. Monaco, R. Paparella, L. Sagliano[1], D. Sertore, Istitituto Nazionale di Fisica Nucleare - LASA, Segrate, Italy
C. Pagani, Università degli Studi di Milano and INFN LASA, Segrate, Italy
A. Miraglia, S. Aurnia, O. Leonardi, G. Vecchio, INFN LNS, Catania, Italy
[1]now at European Spallation Source, Lund, Sweden
[2]now at CERN, Geneve, Switzerland

Abstract

INFN-LASA contributes in-kind to the European Spallation Source ERIC with 36 (plus two spares) 6-cell cavities for the Medium Beta section of the Superconducting Linac. After having developed the electromagnetic and mechanical models, few prototypes have been produced and tested. Based on this experience, we are now supervisioning the cavity production at the industry, the resonators test at DESY and the delivery to CEA at Saclay. In this paper, we report on the status of the overall INFN-LASA contribution including also document handling, interface data exchange and QA/QC.

INTRODUCTION

The European Spallation Source, now in the installation phase at Lund (Sweden), will accelerate a proton beam up to 2.0 GeV to produce, by the spallation process, neutrons to investigate fundamental process of the physical world.

The accelerator complex is composed of different sections as reported in Fig. 1. INFN LASA contribution is focused on the Medium Beta (MB, $\beta = 0.61$) cavities [1] to be used to accelerate the proton beam from 216 to 571 MeV. In collaboration with CEA, our cavities will be integrated into cryomodules in France before being delivered to ESS for installation into the tunnel.

INFN LASA has started working on this type of cavity developing its electromagnetic and mechanical design. The rationale of our design has been to improve the cell-to-cell coupling to improve HOM extraction and mode separation at the expense of a slightly higher E_{peak}/E_{acc} and reductions of R/Q [2]. Moreover, an extensive work was done to identify trapped monopoles modes below the cut-off frequency of the beam pipes, not having this cavity any HOM damper [3].

Based on these studies, a prototype has been fabricated in collaboration with the industry to establish a validated procedure for the upcoming series production. The results obtained have been extremely encouraging, largely overcoming the ESS specifications [4]. The prototype has been afterwards integrated, together with other three CEA cavity prototypes, in the demonstrator module M-ECCTD assembled and successfully tested at CEA [5].

In 2016 we have launched the international call for tenders for the Niobium materials and for the cavity fabrication. The tenders were selected and the contracts awarded about six months later.

NIOBIUM MATERIAL

All the Niobium parts needed for the fabrication of the ESS cavities have been delivered by OTIC Ningxia. The 482 sheets have been delivered in three lots while the remaining parts have been shipped with the first lot of sheets.

All the Nb sheets have been eddy current scanned at DESY to detect mainly inclusions of foreign materials but also geometrical imperfections (scratches, thinner sheets, etc.). By this analysis, the side to be exposed to RF is detected.

Figure 2 reports the results of the scanning identifying also the reasons for sheets non-conformity. None of the sheets has inclusions. Few of them have some scratches and only one was thinner than the requested tolerances. More than 80 % of the sheets have been accepted after the scan of the first side while the overall acceptance level is larger than 98 %.

CAVITY PRODUCTION CYCLE

Fabrication and Preparation for the Test

Based on the experience of the XFEL production, a "built to print" production process has been chosen also for the ESS MB cavities. This process consists in setting stringent requirements on the specifications while not asking the producer for granted performances.

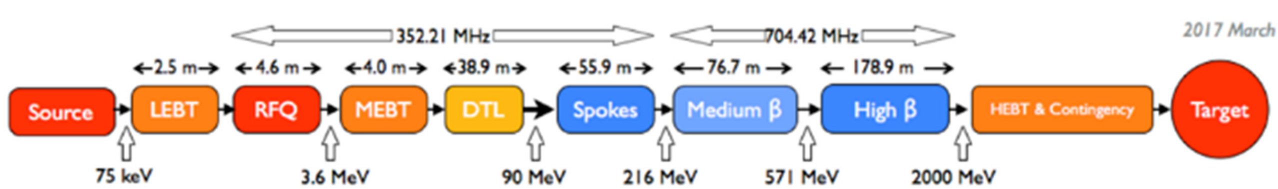

Figure 1: Layout of the ESS superconducting linac. INFN LASA is responsible for the medium beta section.

† paolo.michelato@mi.infn.it

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS119

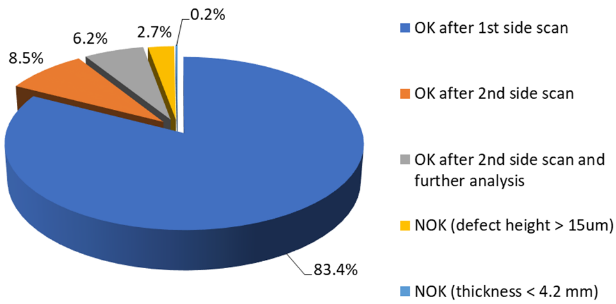

Figure 2: Nb sheets scanning results. More than 92 % of them has been accepted after second scan and 98 % after further analysis to exclude possible inclusions.

The cavity fabrication process starts by water jet cutting the square sheets to circular shape and then deep drawing them to form the half cells. Our cavity design foresees three types of Half Cell (HC), namely Inner, Pen and End HCs.

The HCs are then electron beam welded (EBW) to form Inner and Terminal Dumb Bell. The End Cell are EBW to the end tube group to form the End Group. See Ref. [6] for a more detailed description of the cavity assembly process. After mechanical and RF measurements, every component is trimmed to ensures to reach the proper frequency and length of the final cavity. The present status of the subcomponents mechanical fabrication and cavities after welding is summarized in Table 1.

Table 1: Present Status of the Mechanical Production from Subcomponents to Cavities

Component	Produced	Expected
Half Cells	192	304
Pen Cells	48	76
End Cells	48	76
Inner DB	72	114
Terminal DB	36	76
End Groups	36	76
Cavities	18	38

The cavity is then chemical etched to remove the damage layer of the inner part of the cavity. It consists of a total of 200 µm "bulk BCP" etch, 90 µm with the coupler up and the remaining with the coupler down. Afterwards, the cavity is heat treated in vacuum at 600 °C for 10 hours. It is then tuned to the proper frequency and field flatness before being integrated into the He-tank. The final step is the installation of the accessories (pick antenna, main coupler high Q antenna, flanges, etc.) and a "final BCP" of 20 µm to prepare the cavity for the test. A dedicated paper related to the surface treatment of the ESS cavities is presented at this conference (see Ref. [7]) where more details of the surface treatment are discussed.

Figure 3 reports a typical frequency variation along the full cavity preparation cycle. The large frequency variation at the beginning is due to the "bulk BCP" process. The final Field Flatness of the cavity is larger than 93 % as requested from ESS specifications.

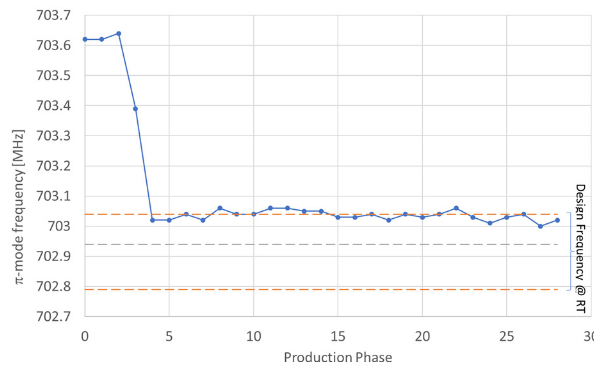

Figure 3: Frequency evolution during the cavity production cycle. The large variation at the beginning is due to the "bulk BCP" process.

At present four lots of subcomponents (each corresponding to parts for 6 cavities) have been produced. 18 cavities have been EBW and 15 of these have been treated up to the "bulk BCP". Up to now, four cavities have reached the "final BCP" and they have proceeded to the following test phase.

Vertical Test at DESY

The cavity, after complete preparation, is shipped to DESY for its qualification in cryogenic conditions. A vertical insert allows to test a pair of cavities. Each single cavity is tested up to its limits in order to assess the performances at the ESS working point and the maximum accelerating gradient attainable. Moreover, also the frequencies of the first monopole passband mode at cold and the HOM spectra are measured as part of the qualification before installation. More information on the tests and these kinds of measurements are extensively discussed in Ref. [8].

Figure 4 summarizes of the results of the cavities tested up to now.

Handover and Delivery to CEA

After successful test at DESY, the cavity is prepared to be shipped to CEA where it will be integrated in the cryomodule. A careful outgoing inspection is performed, and these data and the vertical test results are submitted to ESS that takes the final decision on the acceptance of the cavity. This defines also the property handover of the cavity from INFN to ESS.

QUALITY ASSURANCE AND CONTROL (QA/QC)

The production of the ESS MB cavities needs the supervision and quality control of many components. A critical task is assuring and controlling the production from the Half Cells to the final cavity ready to be delivered for test and installation. For this purpose, we have developed specific procedures and tools to monitor the evolution of the production and to follow single components.

The strategy we have developed and applied to ensure proper QA/QC of the production process has already been

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS119

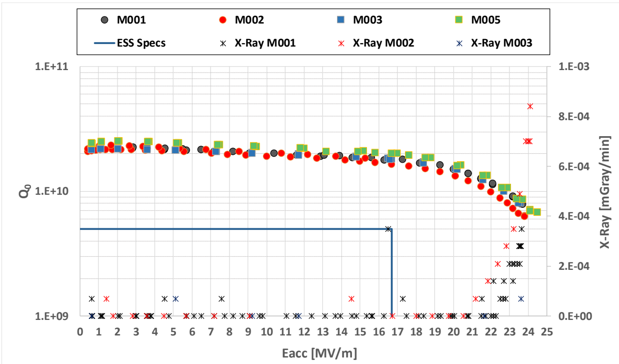

Figure 4: Summary of the vertical test for the four cavities tested up to now at DESY.

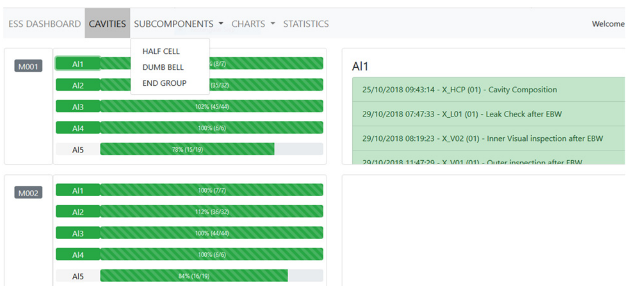

Figure 5: ESS dashboard with detailed information about the status of the cavities.

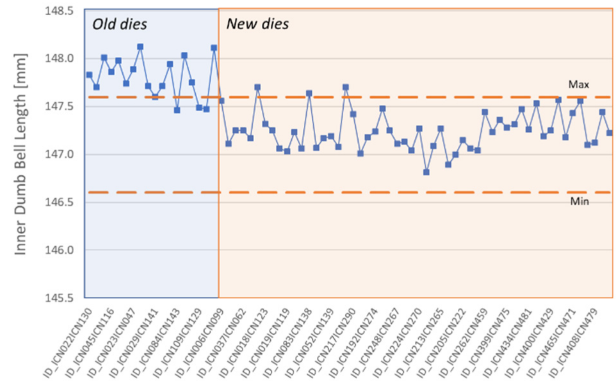

Figure 6: Example of scatter of measurements on length of Inner Dumb Bell before trimming. This is a typical plot available on the ESS Dashboard.

reported [9], along with how we have extended it also to the test phase in DESY and the delivery at CEA. To briefly summarize it, we have developed control sheets and detailed reports that the company and the involved labs needs to fill and follow that allows cross checking different phases of the cavity cycle. Five acceptance levels correspond to hold points where the results and the related documentation is controlled and if they conform to specifications the cavity proceed to the next level.

The most significant information contained in the control sheets are extracted and collected into a database. A graphical interface, ESS Dashboard, allows having an overview of the production process at glance both for subcomponents and for cavities. Figure 5 shows an example of the cavity summary panel where the status of the cavity with respect to its advance in the production process is shown.

The database allows also the analysis of the production nearly online to monitor trends and, eventually, deviation with respect the standards. As an example, Fig. 6 reports the evolution of the Inner Dumb length before the final trimming. The large step of ID length is due to the change in the stamps used for the subcomponents deep drawing. After this change, the components are now within the expected tolerances except for few components that have been accepted only after the notification of non-conformity and a more detailed analysis on the possible consequences in the cavity composition.

Up to now, about hundred Non-Conformity reports have been issued during the production process but only few were related to the cavity interface and hence might have had impact on the cavity installation. All of them have been positively resolved and accepted by ESS after discussion with our colleagues at CEA allowing installation of the cavities.

CONCLUSIONS

We have presented the status of the ESS Medium Beta cavity production.

We have produced so far mechanical subcomponents for more than half of the full production and half of the cavities. The treatment process has highlighted some defects that have been cured and preventive actions have been identified.

Before summer, eight more cavities will be tested and delivered to CEA as foreseen by the ESS schedule and the other are expected to be on time.

REFERENCES

[1] P. Michelato *et al.*, "INFN Milano - LASA Activities for ESS", in Proc. *17th Int. Conf. RF Superconductivity (SRF'15)*, Whistler, Canada, Sep. 2015, paper THPB010, pp. 1081-1084.

[2] P. Michelato *et al.*, "ESS Medium and High Beta Cavity Prototypes", in Proc. *7th Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, pp. 2138-2140. doi:10.18429/JACoW-IPAC2016-WEPMB011

[3] S. Pirani *et al.*, "Investigation of HOM Frequency Shifts Induced by Mechanical Tolerances", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 1071-1073. doi:10.18429/JACoW-IPAC2017-MOPVA091

[4] A. Bosotti *et al.*, "Vertical Tests of ESS Medium Beta Prototype Cavities at LASA", in Proc. *8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 1015-1018. doi:10.18429/JACoW-IPAC2017-MOPVA063

[5] P. Bosland *et al.*, "Tests at High RF Power of the ESS Medium Beta Cryomodule Demonstrator", presented at the *10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, paper TUPTS006, this conference.

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS119

[6] L. Monaco *et al.*, "Fabrication and Treatment of the ESS Medium Beta Prototype Cavities", in Proc. *8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 1003-1006. doi:10.18429/JACoW-IPAC2017-MOPVA060

[7] M. Bertucci *et al.*, "LASA Activities on Surface Treatment of Low-beta Elliptical Cavities", presented at the *10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, paper TUPTS118, this conference.

[8] A. Bosotti *et al.*, "Vertical Test of ESS Medium Beta Cavities", presented at the *10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, paper WEPRB023, this conference.

[9] D. Sertore *et al.*, "INFN- LASA Medium Beta Cavity Prototypes for ESS Linac", in *Proc. SRF'17*, Lanzhou, China, Jul. 2017, pp. 494-498. doi:10.18429/JACoW-SRF2017-TUPB048